Empowering the Next Generation:

The Role of Team Hierarchy in Retaining Junior Researchers

Abstract

Early-career scientists are essential to driving scientific progress, yet nearly half leave academia after their first publication. While factors like team size, gender, mentorship, and institutional prestige are known to affect retention, the influence of team hierarchy on junior researchers' career paths remains underexplored. This study investigates how hierarchical structures within research teams impact the retention of junior scientists, using Microsoft Academic Graph data from over 30 million teams across 19 disciplines. We define retention as a combination of paper publishing (continue publishing), academic independence (continue publishing without depending on the same senior authors), and career progression (change institution). Team hierarchy is measured through the Gini coefficient of career age for all team members. We reveal that flat team structures support the retention of junior researchers with a career age of 5 years or less, especially in social science and small teams. These findings remain robust when accounting for diverse individual- and team-based variables and are consistent across different disciplines. Our findings provide insights that can inform team composition, ultimately contributing to more sustainable academic careers for early-career scientists.

Introduction

Young scientists are thought to be key drivers of scientific innovation [1–3]. However, the prospects for early-career scientists in academia are becoming increasingly challenging. Almost half of the researchers leave science after publishing their first paper [4] (SI Fig S1). The decline in tenured positions and the increasing difficulty of securing funding further exacerbate the situation [5,6]. Given the prevalence of teams across scientific fields [7], it is crucial to better understand the conditions that support junior researchers' success in team environments. Research suggests that factors such as team size[8], gender[9], mentorship[10], institution prestige[11] influence the retention junior researchers. However, the impact of team hierarchy on junior researchers' retention remains unclear.

Although previous research shows flat team structure relates to team innovation and long-term citations in science[12,13], little is known about how team hierarchy affects individual performance with a large-scale dataset, especially for junior researchers at the bottom of hierarchy. The benefits and costs of team hierarchy for low-power members have been studied in other domains such as business and society [14–17]. The advantages of a hierarchical team structure include creating a psychologically safe environment by reducing responsibility for lower-power members, motivating success through hierarchy-related incentives, and supporting division of labor and coordination among both higher- and lower-power individuals [14,15]. However, the negative aspects of hierarchy, as highlighted by the conflict theory, suggest that inequality over limited resources can trigger struggles within teams [16]. Additionally, the salience of power dynamics indicates that subordinates may be reluctant to voice their opinions, even though hierarchy can provide safety and certainty. Especially when leaders' power is especially pronounced, members may fear speaking up, potentially hindering collective learning and information sharing [17]. Given the importance of team hierarchy for low-power junior researchers, we investigate how team hierarchies affect junior researcher's retention in academia.

Results

Team environments: Measuring team hierarchy

Drawing on Microsoft Academic Graph (MAG)[18] from 30,741,987 teams across 19 academic fields, we investigate how the steepness of team hierarchy influences the retention of 69,794,286 junior researchers. Team hierarchy is defined as the extent of inequality in authority across the team members[15,19], which is quantified using the Gini coefficient of career age[13,20]. In Fig 1a, we depict five example teams ranked by their hierarchy based on career age distribution. A higher Gini coefficient reflects greater disparity, indicating a steeper hierarchy where a senior member possesses substantially more experience and likely exerts greater influence, while the majority have significantly less experience and authority (e.g., Fig 1A case 4-5). In contrast, a lower Gini coefficient suggests that team members share similar career experience (e.g., Fig 1a, case 1) or that multiple senior researchers share leadership responsibilities within the flat structure team (e.g., Fig 1a, case 2). Career age serves as a proxy for authority and experience[20–22], and we also evaluate other proxies, such as connections (number of collaborators) and productivity (number of publications) in SI Fig S4. We define junior researchers as those with five or fewer years of career experience and senior researchers as those with more than five years. Career experience is traced from a researcher's first paper to the focal paper (Please refer to Materials and Methods for more details). Recognizing that junior researchers often require mentorship and leadership support from senior researchers to retain and publish papers [23,24], we focus on teams that consist of at least one junior and one senior researcher. Our primary interest is whether junior researchers can retain and continue publishing, considering the hierarchical structure of their teams. In Fig 1b, we present the distribution of team hierarchy across the full dataset, with the five cases from Fig 1a highlighted. Fig 1c reveals that, as team size increases, team hierarchy tends to become steeper, aligning with findings from previous research [12]. Fig 1d demonstrates that in recent years, team hierarchies have tended to flatten.

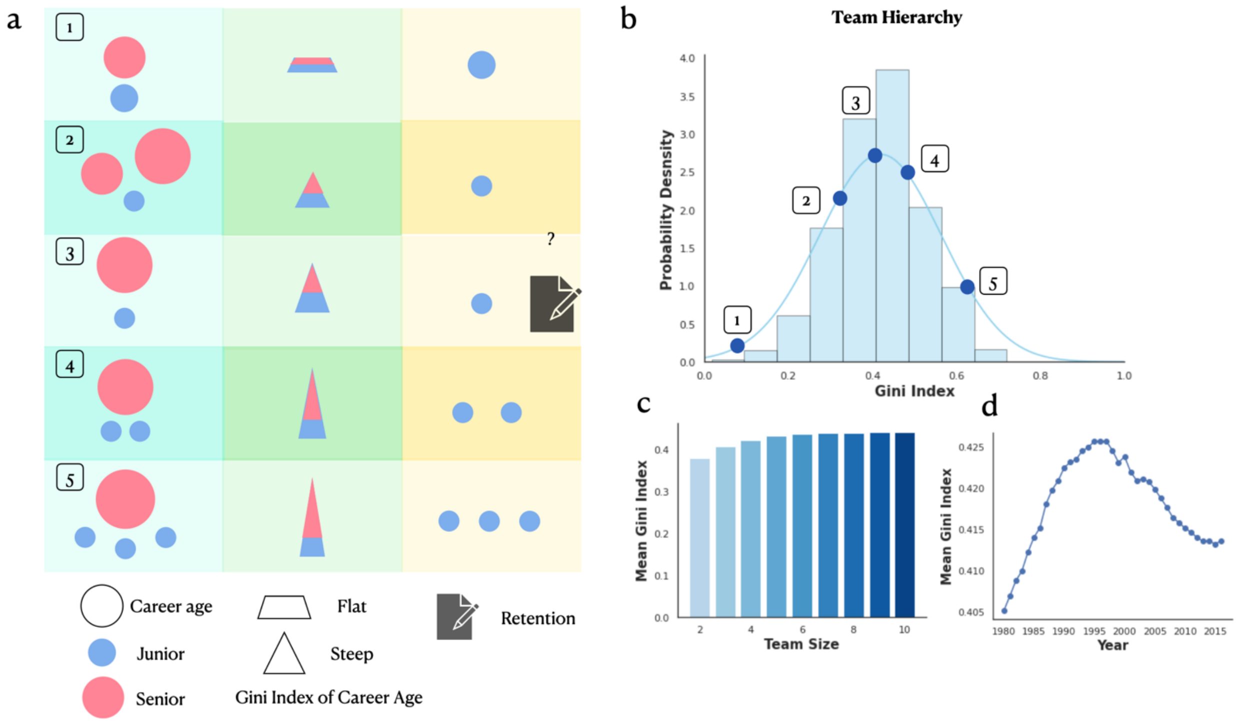

Fig 1. Measurement of Team Hierarchy. **(a)** We identify five typical cases in which junior and senior researchers form teams, ranked by the degree of team hierarchy, ranging from flat to steep structures. Junior researchers are defined as those with a career age of five years or less, while senior researchers have a career age greater than five years. Team hierarchy is measured by the Gini index, which quantifies the disparity in career age among co-authors of a paper. In the flattest hierarchy (case 1), junior and senior researchers have similar career ages. In the second flat structure (case 2), two senior researchers share leadership responsibilities. In contrast, in steeper hierarchies (cases 3–5), a senior researcher possesses substantially more career experience, while other junior members are relatively new to academia. Our goal is to examine how team hierarchy impacts junior researchers' retention in academia. **(b)** The distribution of team hierarchy across 30,741,987 teams, with the five cases from **(a)** highlighted. **(c)** Team hierarchy becomes steeper as team size increases, ranging from two to ten team members (29,392,205 teams, representing 96% of all teams). **(d)** From 1980 to 1995, team hierarchy became steeper but flattened between 1995 and 2016. Additionally, we consider other measures of team hierarchy, such as the Gini index of connections (number of collaborators) and productivity (number of publications) (SI Fig S4).

Flat structure enhances junior researchers' retention

We define retention in academia using three distinct measures, as shown in Fig 2a. In our research, retention for junior researchers in science is defined as continuing to publish papers, gaining academic independence, and achieving career progression. Specifically, retention is first measured by assessing whether an individual continues to publish papers within five years following the publication of their focal paper [4,25]. To prevent reliance on the same senior co-authors, we then define academic independence as publishing at least one paper without the same senior co-authors within the next five years. Retention is also evaluated by whether the junior researcher transitions to a new institution, such as securing a tenure-track position, a postdoctoral role, or pursuing further studies. These three criteria—paper publishing, academic independence, and career progression—are all considered essential indicators of retention in our study. Junior researchers with lower career age exhibit lower retention rates, especially those with fewer than five years of experience (SI Fig S1). When team hierarchy becomes steeper, junior researchers' ability to continue publishing papers declines sharply. These findings remain consistent even when junior researchers are defined as those with a career age of less than 1 to 5 years (Fig 2b). Among all variables examined—such as gender, institution tier, authorship, mean senior career age, team size, and year—team hierarchy emerges as the most important predictor of retention (Fig 2c and SI Table 1). To ensure that retention is not merely the result of continued collaboration with the same senior researchers, we also calculate retention rates for junior researchers who publish without depending on the same seniors and those who transition to a new institution (Fig 2d-e). The results remain consistent: junior researchers in flat team structures exhibit higher retention rates compared to those in hierarchical structures. Moreover, retention rates are higher in flatter team structures not only for junior researchers with fewer than five years of experience but also for all researchers, including senior ones (SI Fig S2).

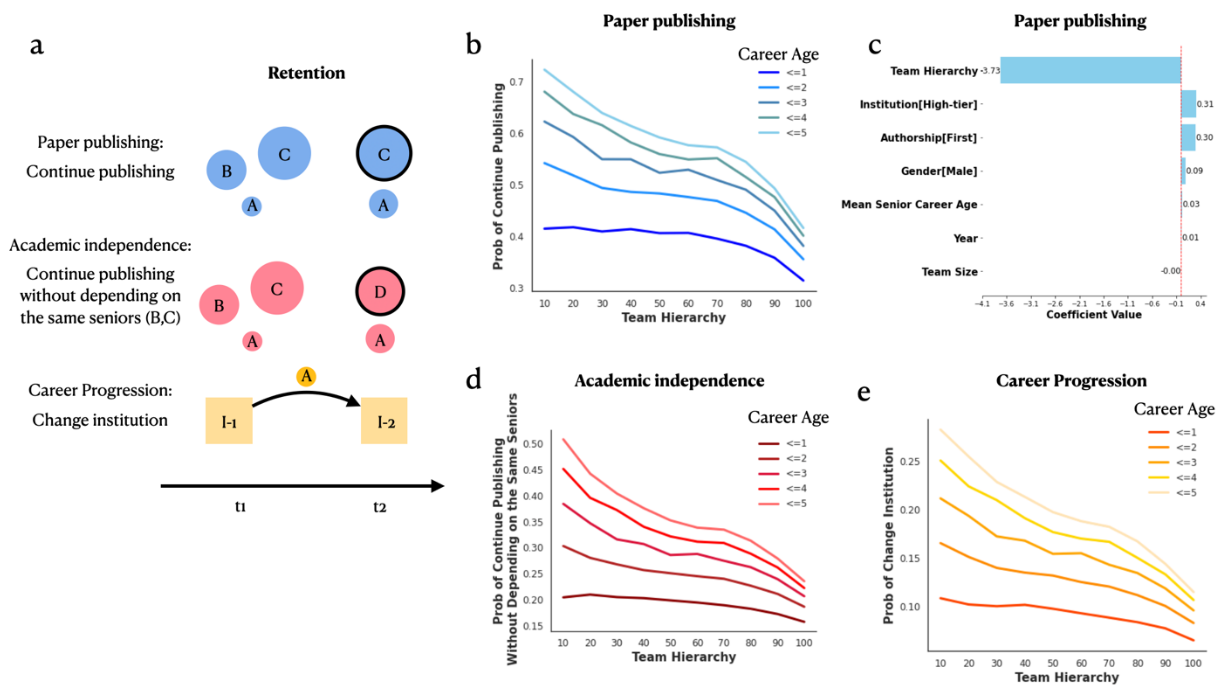

Fig 2. Flat structure enhances junior researchers' academic retention in continue publishing, academic independence, and career progression. **a.** Paper publishing: This measures whether a junior researcher (A) continues publishing within five years after their focal paper, serving as a clear indicator of staying active in academia. Academic Independence: we emphasize the importance of independence of the junior researcher

A by requiring at least one paper published without the same senior co-authors (B, C), which addresses the concern about being overly reliant on a specific team or mentor. Career Progression: we capture the growth aspect of retention by measuring whether the junior researcher moves to a new institution (from I-1 to I-2), signaling career development through tenure-track positions, postdoctoral roles, or further academic study. **b.** For junior researchers with a career age of less than 1 to 5 years (measured as the time from their first publication to the focal paper), the percentage of those continuing to publish decreases as team hierarchy becomes steeper. Team hierarchy, defined as the disparity of authority among team members, is measured by the Gini index of career age among coauthors in a paper. Hierarchy is categorized into 10 bins, each representing a 10% increment of the total range, from the 10th to the 100th percentile. **c.** Team hierarchy has the strongest coefficient values predicting paper publishing, academic independence, and career progression (regression models in SI Table 1). The model evaluating the relationship between team hierarchy and paper publishing controls for variables such as institution tier, authorship, gender, mean senior career age, team size, and publication year (detailed measurements are provided in the Methods section). **d.** For junior researchers with a career age of less than 1 to 5 years, the probability of publishing independently—without relying on the same senior co-authors—decreases as team hierarchy becomes steeper over the subsequent five years. **e.** Similarly, for junior researchers with a career age of less than 1 to 5 years, the probability of transitioning to a new institution within the next five years decreases as team hierarchy becomes more pronounced. A detailed description of the measurements is provided in the Methods section.

Retention drivers in flat structures: Robustness across contexts

We further tested the impact of team structure on junior researchers' retention across diverse individual-based and team-based variables. Fig 3a examines gender differences, showing that male junior researchers have higher retention rates than their female counterparts, consistent with prior research [9,25]. In Fig 3b, junior researchers affiliated with high-tier institutions demonstrate higher retention rates compared to those at low-tier institutions, aligning with previous findings [11]. Fig 3c highlights the role of authorship position, revealing that junior researchers in first-author positions have higher retention rates than those in other team roles, as first authors typically contribute more significantly to research outputs than middle authors [22]. Fig 3d indicates that junior researchers in teams with lower average senior career age have lower retention rates than those in teams with higher senior career age, except for teams in the highest career age percentile. This suggests that middle-career senior researchers are most beneficial for supporting junior researchers' retention. In Fig 3e, the relationship between team size and hierarchy is explored. Junior researchers in smaller teams (<=3 team members) experience a sharper decline in retention rates as team hierarchy becomes steeper compared to those in larger teams. This finding enriches existing research, suggesting that while small teams can promote junior researchers' retention, this effect is contingent on flatter hierarchical structures [8]. Finally, Fig 3f illustrates that junior researchers in teams formed in more recent years display higher retention rates than those in teams formed in earlier periods, reflecting potential changes in collaboration dynamics or academic environments over time.

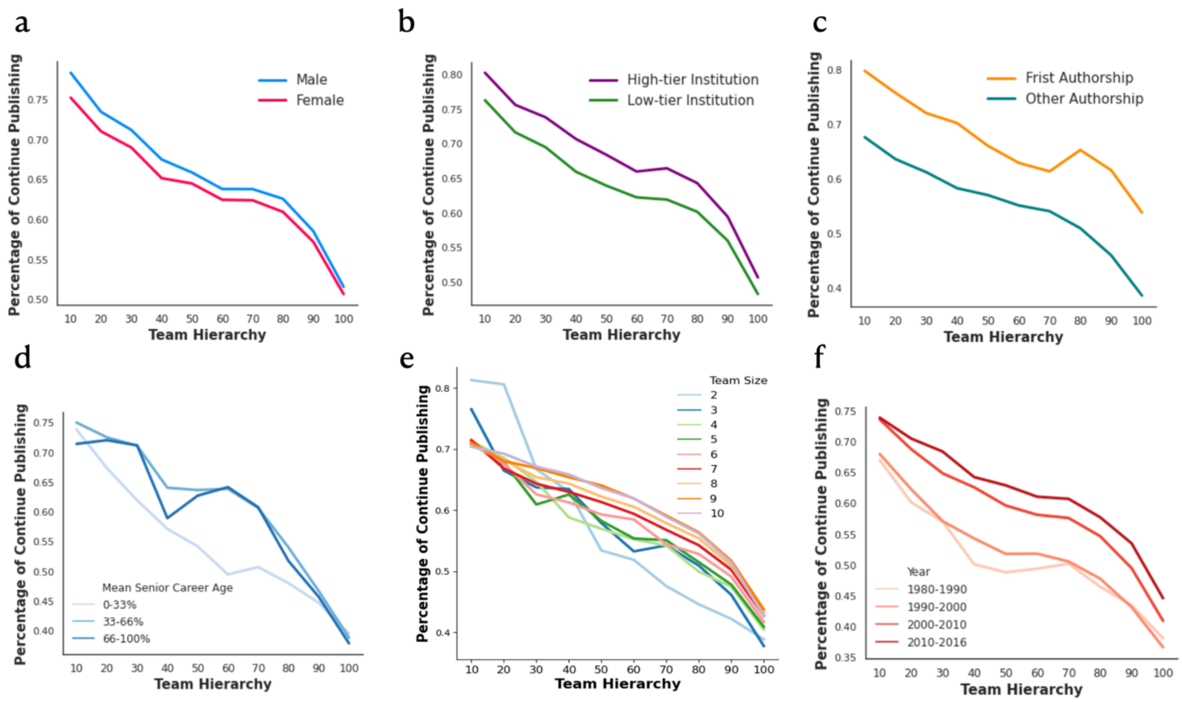

Fig 3. Flat structure boosts junior researchers (career age <= 5) in continuing publishing across individual related variables – gender, institution, and authorship, and team related variables –mean senior career age, team size, and year. **a.** Male junior researchers have higher retention rates than female junior researchers. **b.** Junior researchers in high-tier affiliations exhibit higher retention rates compared to those in low-tier affiliations. **c.** First authors have higher retentions than junior authors in other positions. **d.** Junior researchers in teams with seniors in the middle mean career age percentiles (33–66%) show the highest retention rates, compared to those in teams with seniors in the lowest (0–33%) and highest (66–100%) percentiles. **e.** Junior researchers in smaller teams (2–3 members) have higher retention rates in flat structures, while those in larger teams (4–10 members) show higher retention rates in hierarchical structures. **f.** Junior researchers in teams from more recent years have higher retention rates compared to those in teams from older years. A detailed description of the measurements is provided in the Methods section.

Social science and small teams: Key factors in retention within flat structures

We categorize 19 academic disciplines into three fields: science & engineering, social sciences, and humanities & arts. Flat structures enhance the retention of junior researchers (career age ≤ 5) across these three fields (Fig 4a). Specifically, in flat structures, junior researchers in social science fields exhibit the highest retention rates, followed by those in science & engineering, with the lowest retention observed in humanities & arts. In contrast, under hierarchical structures, junior researchers in science & engineering have higher retention rates than those in social sciences. We fit the slope of the percentage of continuing publications and team hierarchy using a linear regression model, showing the results for all 19 disciplines in Fig 4b (detailed visualization in SI Fig S5). This reveals that hierarchical structures are associated with lower retention rates for junior researchers across all 19 disciplines. Within the science & engineering fields (chemistry, materials science, physics, and biology), the slope is smaller than in social science fields (business, sociology, and economics), indicating that steeper team hierarchies disproportionately impact junior researchers in social sciences. These results remain consistent across different team sizes and time periods (Fig 4e-d). In small teams (with 3 or fewer members), junior researcher retention shows a sharper decline as team hierarchy becomes steeper, compared to larger teams across all three fields, as shown in Fig 4c. Over time, retention of junior researchers who continue publishing increases in all three fields (Fig 4d).

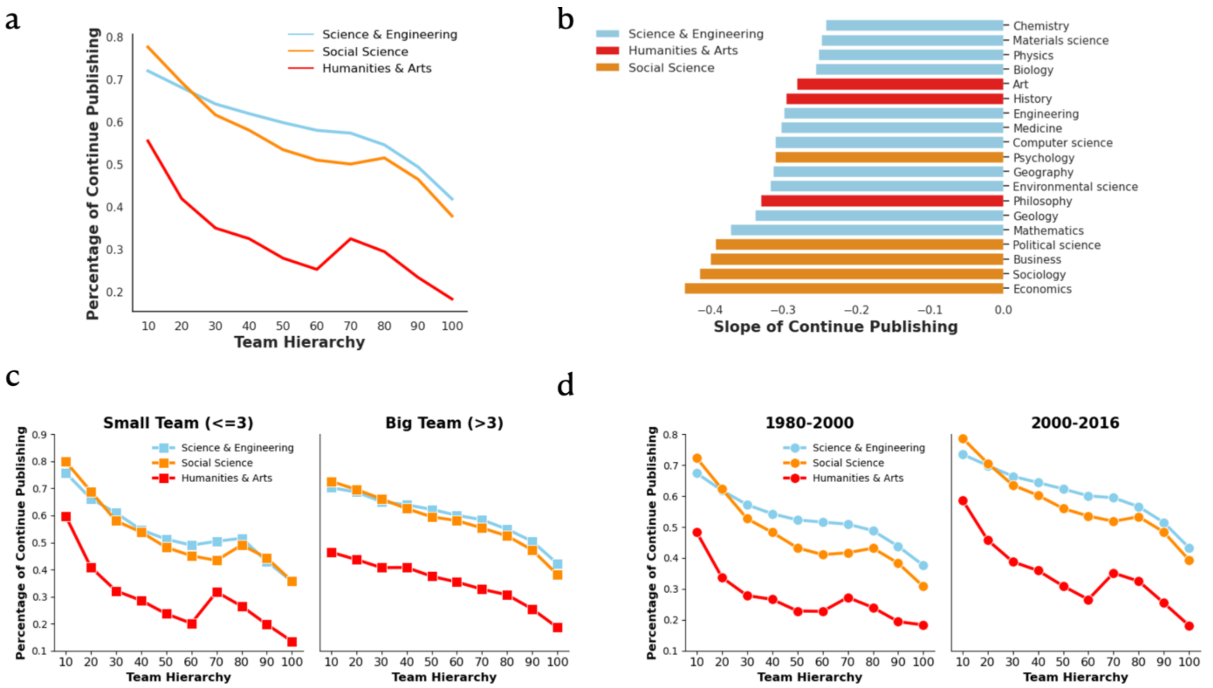

Fig 4. Flat structure increases the probability of junior researchers in continuing publishing in social science than in science. **a.** There are in total 19 top level disciplines. In flatter structure, junior researchers in science & engineering (blue) have lower retention than those in social science (orange), but it is the opposite in hierarchical structure. The decrease of social science is shaper than science fields as team hierarchy decreases. **b.** In specific 19 disciplines, we fit the slope of percentage of continue publishing vs team hierarchy with linear regression model. Junior researchers in social science disciplines have lower slope (orange) than those in science & engineering disciplines (blue). **c.** These results remain consistent for junior researchers across different team sizes. For junior researchers in smaller teams (>3 members), the decline in continuing publication as team hierarchy increases becomes sharper across all three fields. **d.** The results are also consistent across different time periods. From 1980–2000 to 2000–2016, the retention of junior researchers continuing to publish increases across all three fields.

We also distinguish three different team sizes, small teams (2-3), medium teams (4–5 members), and large teams (6–10 members). In small teams, flat structures lead to higher retention rates for junior researchers. By contrast, in large teams, hierarchical structures are associated with higher retention rates (Fig 5b). This indicates that team hierarchy has a more detrimental impact on junior researchers in small teams than in large teams. However, small teams contribute more to driving team innovation compared to large teams [26]. Using a linear regression model, we fit the slope of the percentage of paper publishing against team hierarchy and show the results for junior researchers in teams ranging from 2 to 10 members in Fig 5b (detailed visualization in Fig 3e). The analysis reveals that as team size increases, the slope trend decreases, further confirming that steeper team hierarchy disproportionately affects junior researchers in small teams compared to those in large teams. These results remain consistent across different authorships, time periods (Fig 4e-d) and gender (SI Fig S6). Compared to first authors, junior researchers in other authorship positions experience a greater decline in retention as team hierarchy increases, regardless of team size (Fig 5c). Essentially, being in secondary or supporting authorship roles makes junior researchers more vulnerable to the negative effects of hierarchical team structures on their likelihood of continuing to publish. Over time, retention rates for paper publishing improve across all three team sizes (Fig 5d).

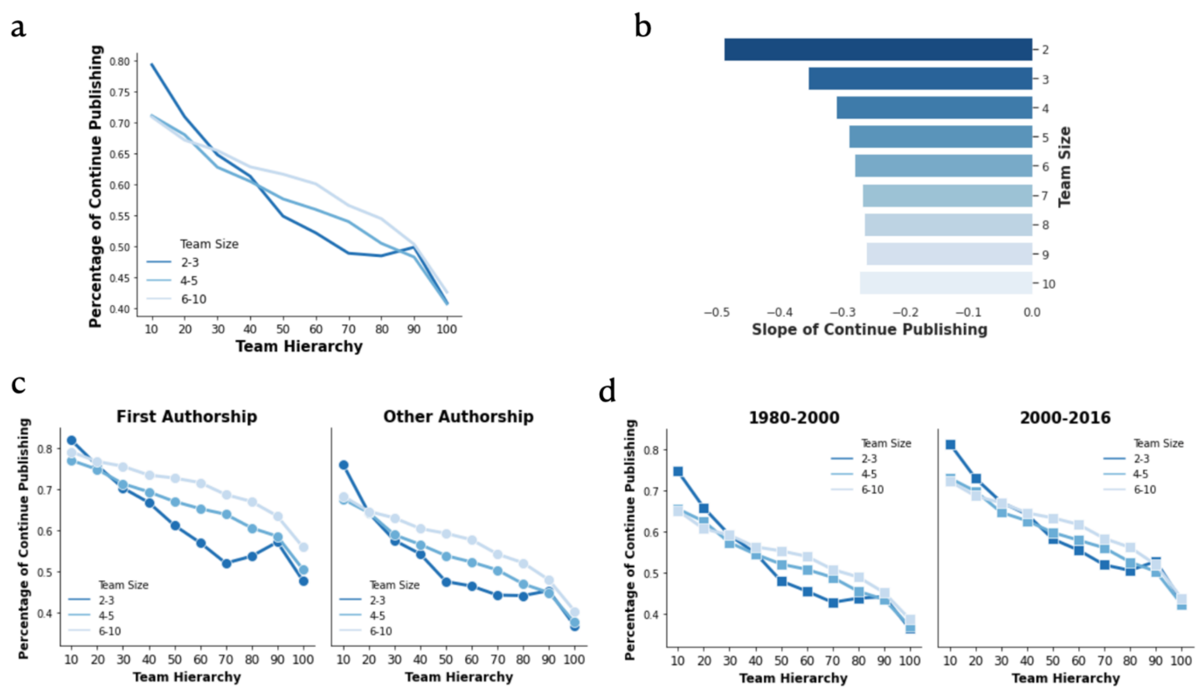

Fig 5. Flat structure increases the probability of junior researchers in continuing publishing in small teams than large teams. **a.** Teams are divided into three size groups: small teams (2–3 members), medium teams (4–5 members), and large teams (6–10 members). 29,392,205 teams are analyzed, representing 96% of all teams. The blue lines become lighter as team size increases. Retention rates for junior researchers in small teams decline more sharply than those in large teams as team hierarchy becomes steeper. **b.** For teams ranging from 2 to 10 members, we fit the slope of the percentage of paper publishing versus team hierarchy using a linear regression model. Junior researchers in smaller teams (darker blue) have steeper slopes than

larger teams (lighter blue). **c.** The results remain consistent for junior researchers across different authorship roles. For junior researchers who are not in first authorship, the decline in retention as team hierarchy increases is sharper across all three team sizes. **d.** The findings are also consistent over time. From 1980–2000 to 2000–2016, the retention of junior researchers continuing to publish increases across all three team sizes.

Discussion

Our study highlights the significant impact of team hierarchy on the retention of junior researchers, offering new insights into the ways that hierarchical structures influence early-career scientists' academic trajectories. By examining over 30 million research teams across multiple fields, we found that the steepness of team hierarchy—captured through career age disparities—affects key indicators of retention, including paper publication, academic independence, and career advancement. Teams with balanced hierarchies may offer junior researchers both the mentorship and autonomy needed for sustainable careers, while steep hierarchies can create barriers to independence and progression.

These findings underscore the importance of carefully structuring research teams to foster supportive environments for junior members. For institutions and senior researchers, this means considering how mentorship, task delegation, and team dynamics contribute to the career sustainability of early-career scientists. Our study emphasizes that by fostering balanced, flat team hierarchies, the academic community can better support the retention and success of emerging researchers, strengthening the future of scientific innovation.

Despite the valuable insights, there are still areas that require further investigation. Future research could investigate the underlying reasons why flat team structures enhance junior researcher retention, focusing on factors such as increased networking opportunities and the promotion of career independence. Additionally, future studies could explore practical strategies for establishing and maintaining flat structures within scientific teams.

This paper has some limitations. First, the definition of a team is based on all co-authors of a paper rather than lab-based teams, which may not reflect the actual team dynamics. Second, team hierarchy is measured using career age or its proxy, rather than direct survey data, which might not fully capture the real authority disparity. Third, authors are classified as junior or senior using a binary approach with a career age cutoff of approximately five years, potentially oversimplifying variations in experience levels. Finally, author disambiguation problems in the MAG dataset could potentially affect the results.

Materials and Methods

Dataset: We selected Microsoft Academic Graph (MAG)[18] dataset, which includes records of papers, authors, and institutions for publications spanning 1980 to 2021. We define papers with at least two authors as teams, resulting in a total of 75,026,432 teams across 19 disciplines. To focus on the retention of junior researchers, we filtered the dataset to include 66,879,903 teams that feature at least one junior researcher with a career age of 5 years or less. Recognizing that junior researchers often require leadership support to publish papers[23,24], we further narrowed the selection to 46,082,207 teams that also include at least one senior researcher, with a career age between 6 and 80 years, to exclude teams composed entirely of junior researchers. We define retention as the continued academic activity of researchers over the following 5 years, enabling us to track junior researchers from 1980 to 2016. In total, 30,741,987 teams comprising 151,727,248 researchers across 19 disciplines meet all the criteria. Of these, 69,794,286 researchers (46%) are classified as junior, with a career age of 5 years or less.

Dependent Variables: The retention of junior researchers. In the regression model, the unit of analysis is the junior researcher within each team. Junior researchers are defined as those with a career age of 5 years or less. We use three measures of retention: (1) Paper Publishing: This measure tracks whether the junior researcher continues to publish within five years after their focal paper, indicating ongoing academic activity. There are 40,759,179 researchers who continue publishing, and 29,035,107 who do not. (2) Continue publishing without depending on the same seniors: This measure emphasizes independence by requiring the junior researcher to publish at least one paper within five years after the focal paper, without co-authoring with the same senior researchers. This addresses concerns about over-reliance on a specific team or mentor. There are 25,035,654 researchers who meet this criterion, and 44,758,632 who do not. (3) Change affiliation: This measure captures career retention by determining whether the junior researcher moves to a new institution within five years after their focal paper. Such a move could signal retention through tenure-track positions, postdoctoral roles, or further academic study. There are 7,856,757 junior researchers who change their affiliation, and 31,460,654 who do not. For 43% (30,476,875) of researchers, affiliation data is missing. Additionally, in SI Fig. S3, we measure the number of papers published within five years after the focal paper as another indicator of retention.

Independent Variables:

Team Hierarchy: We calculate the Gini coefficient of career age within the team members at the time of publishing the focal paper. The Gini coefficient is a measure of inequality, commonly used to assess wealth or income distribution [13]. In this context, it quantifies the disparity in authority within each team. A flat team hierarchy is indicated by a low Gini coefficient, close to 0, meaning that all researchers have similar career ages and there is little variation in authority or professional experience among team members. In contrast, a steeper team hierarchy is reflected in a higher Gini coefficient, which signifies greater differences in authority and professional experience within the team. This suggests that a few team members are very senior and experienced, while most of them are junior. If a researcher has no prior publications, his career age is assigned a value of 1 for the focal paper. For instance, if a researcher's first publication was in 2001, their career age would be 5 in 2005. We also measure team hierarchy using the Gini coefficient of productivity and collaboration (SI Fig S4).

Confounding Variables: There are two levels of confounding variables: team-level and individual-level.

Gender of Junior Researcher: We use the SciSciNet Dataset[27] for gender information, which provides the probability of being female. Researchers with a probability above 50% are categorized as female, while those below 50% are categorized as male. This results in 31,865,044 identified male researchers, 18,433,633 female researchers, and 19,495,609 researchers with unknown gender.

Affiliation Level of Junior Researcher: The H-index is a widely used metric to estimate a researcher's career impact[28]. A researcher's H-index is defined as the highest value of h such that h of their papers have at least h citations, and the remaining papers have fewer than h citations. We compile the full publication list associated with each research institution to calculate an institution-level H-index. We categorize institutions in the top 10% as high-tier (H-index $\geqslant$ 716) and the rest as low-tier affiliations.

Authorship of Junior Researcher: We distinguish between junior researchers holding first-author positions and those holding other author positions. 27% of researchers (18,734,758) are first authors.

Mean Senior Career Age: The average career age of senior researchers in a team.

Year: The publication year of a focal paper, ranging from 1980 to 2016.

Team Size: The number of team members. Teams consisting of 2 to 10 members represent 96% of all teams (29,392,205).

Disciplines: The discipline to which each paper belongs. There are 19 top-level disciplines, which we group into three fields: science & engineering, social sciences, and humanities & arts (Fig 4b).

Additionally, we consider other control variables, such as mean team career age (SI Fig S7).

Supplementary Information

Table 1. Logistic Regression Model for Predicting Retention of Junior Researchers (Career Age <=5 Years)

	Model 1: Paper publishing	Model 2: Academic independence	Model 3: Career progression
Team Hierarchy	**-3.73 (0.003) *****	**-3.24 (0.003) *****	**-3.21 (0.004) *****
Institution [High-tier]	0.31 (0.001) ***	0.25 (0.001) ***	0.50 (0.001) ***
Authorship [First]	0.30 (0.001) ***	0.25 (0.001) ***	0.34 (0.001) ***
Gender [Male]	0.09 (0.001) ***	0.24 (0.001) ***	0.25 (0.001) ***
Mean Senior Career Age	0.03 (0.000) ***	0.02 (0.000) ***	0.03 (0.000) ***
Year	0.01 (0.000) ***	0.01 (0.000) ***	0.02 (0.000) ***
Team Size	-0.00 (0.000) ***	-0.001 (0.000) ***	0.002 (0.000) ***
Intercept	-12.81 (0.057) ***	-9.35 (0.059) ***	-45.13 (0.107) ***
Observations	69,794,286	69,794,286	39,317,411

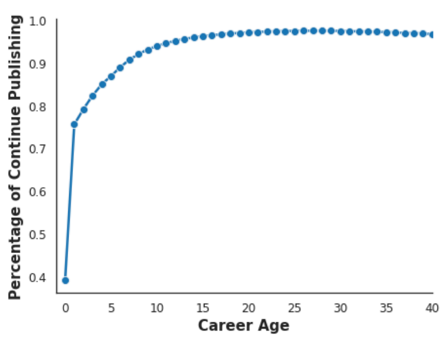

Fig S1. The percentage of researchers who continue publishing is analyzed for career ages ranging from 1 to 40 years. Career age is defined as the time from a researcher's first publication to the publication of the focal paper. Continuing to publish refers to researchers who publish at least one paper within five years after the focal paper. Junior researchers face more significant dropout challenges and exhibit lower retention rates compared to their senior counterparts.

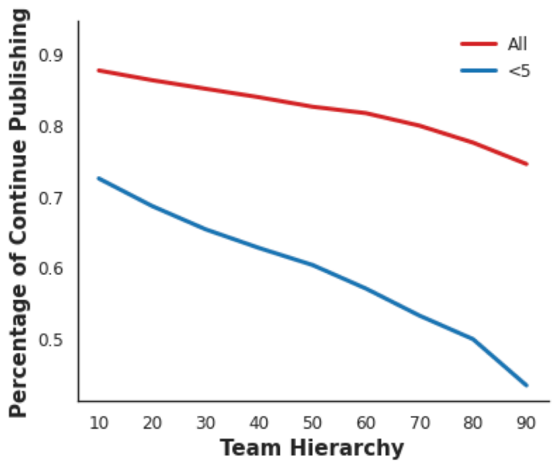

Fig S2. Flat team hierarchies benefit both junior and senior researchers, helping them stay in academia and continue publishing.

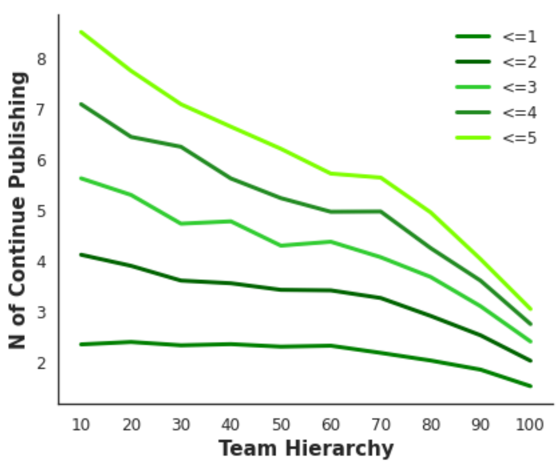

Fig S3. The number of papers published within five years after the focal paper decreases for junior researchers aged 1 to 5 as team hierarchy increases. Career age is defined as the time from the publication of the first paper to the focal paper. Team hierarchy is measured by the Gini index of career age among coauthors, reflecting the disparity of power within the team. Team hierarchy is plotted in 10 bins, each representing a 10% increment, ranging from the 10th to the 100th percentile.

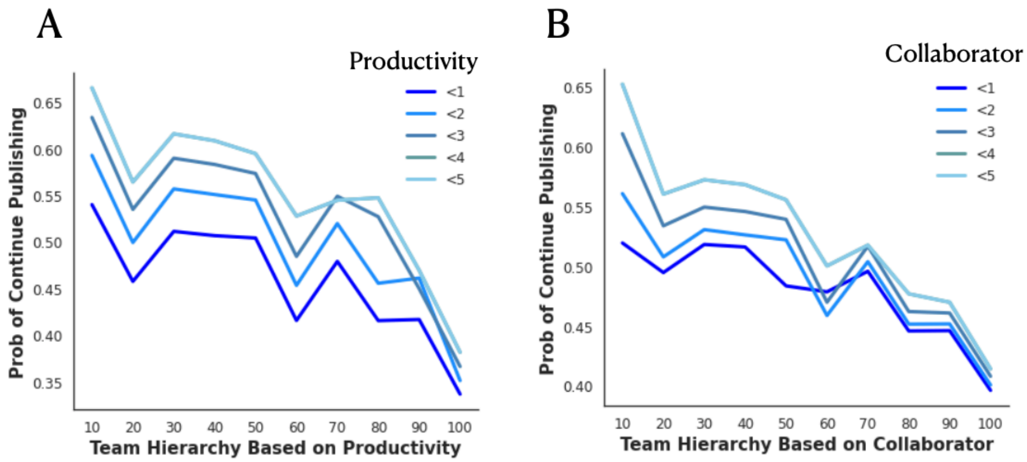

Fig S4. Validation of team hierarchy based on productivity and collaborator **a.** Team hierarchy is measured using the Gini index of productivity, which reflects the disparity in the number of publications before the focal paper among coauthors. **b.** Team hierarchy is measured using the Gini index of collaborators, which reflects the disparity in the number of collaborators before the focal paper among coauthors. In both cases, the trend is consistent: as team hierarchy increases, the probability of continuing to publish decreases.

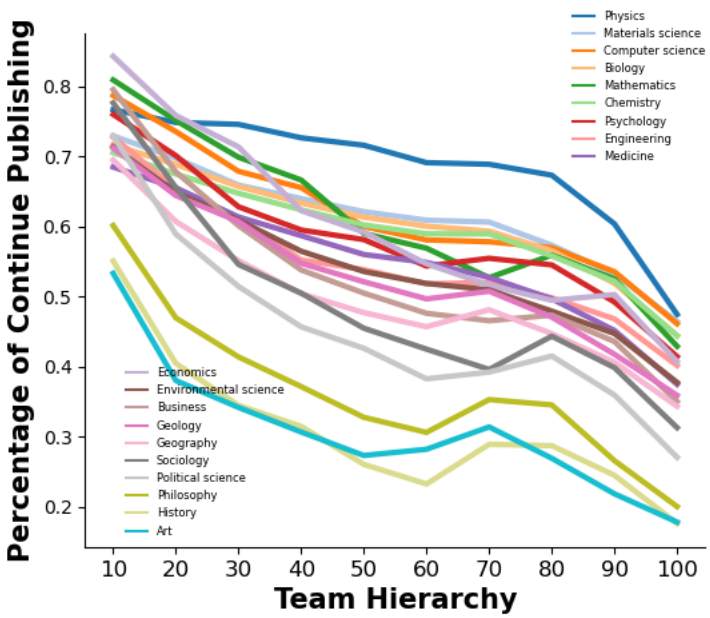

Fig S5. Flat structure enhances retention for junior researchers (career age ≤ 5) across 19 disciplines.

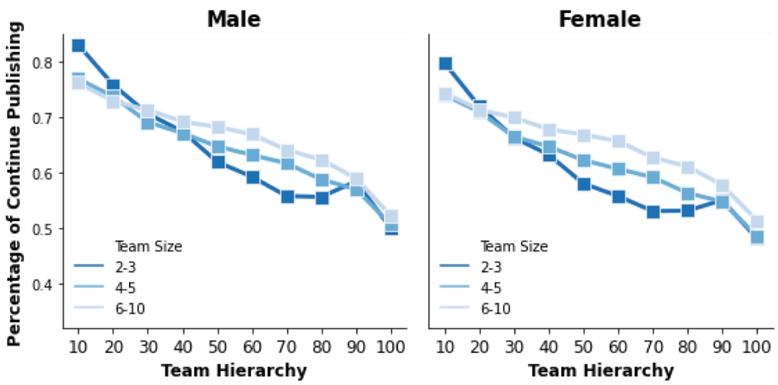

Fig S6. Flat structure increases the likelihood of continuing publishing in small teams compared to large teams, regardless of the junior researchers' gender. Male junior researchers have higher retention rates than female junior researchers across different team sizes.

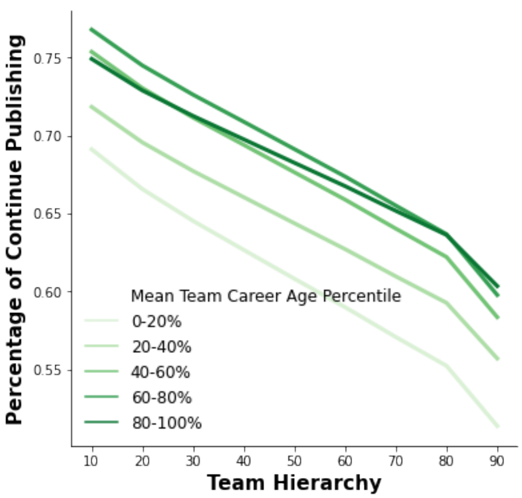

Fig S7. Flat structure enhances the probability of continue publishing across different mean team career age percentiles, especially in teams with 60-80% mean team career age. The mean team career age is the average values of career age for all team members.

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